SUSTAINABLE CASSAVA (*MANIHOT ESCULENTUM*) PRODUCTION IN THE RAIN FOREST AGRO-ECOLOGICAL ZONE OF OSUN STATE, NIGERIA

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ABSTRACT
Different tillage practices of cassava (Manihot esculentum) plants, roots' yield and quality in the rain forest of Osun State, Nigeria were studied. Plots of land were planted with bitter variety 98/0581 fresh cassava stems. Three treatments: zero tillage (0), minimum tillage (1) and maximum tillage (2) were used; each treatment replicated thrice; 0A, 0B, 0C; 1A, 1B, 1C and 2A, 2B, 2C respectively. Selected agronomic parameters (i.e. Heights of cassava plants, Leaf Area Index (LAI), weights of harvested roots per hectare, and quality of roots) were determined. All collected data were analyzed using one-way analysis of variance – ANOVA. Results showed statistical differences among (1) mean values of the heights of cassava plants, (2) mean areas of cassava leaves. There were stronger correlations depicting stronger relationships between methods of tillage and LAI and average growth rate of cassava; R^2 = 0.999, 0.998, 0.996 for zero, minimum and maximum tillage respectively for LAI and R^2 = 0.989, 0.991 and 0.992 for zero, minimum and maximum tillage respectively for average growth rate. The highest yield of cassava roots was 11.33 t/ha in maximum tillage, zero tillage gave lowest, 10.77 t/ha representing 5.2% decrease. Maximum tillage resulted in high quality cassava tubers in term of nutrient composition than other tillage methods. Farmers in rain forests are encouraged to till soil to maximum level so that they will have more income, rural development and livelihoods of farmers will be guaranteed together with right management of land and natural resources.

Keywords: Cassava, Tillage, Rain forest, Leaf Area index

1. INTRODUCTION
Cassava (*Manihot esculentum*) is a tropical tuber broadly categorized into bitter cassava (*Manihot utilisssima*) and sweet cassava (*Manihot palmate*). It is between 2 m and 3 m tall when fully matured, some species may reach up to 4 m height and their maturity period ranges between 9 months and 2 years (IITA, 2017).

Tillage encompasses different soil cultivation systems using mechanical/manual equipment before planting. It is a disruptive and energy-intensive task that should be limited to modifying the soil to alleviate productivity constraints in the rooting zone. The tillage depth of soil depends on factors like the soil developmental stages, equipment' properties like orientations and tilting angle of discs (Lamidi, *et al.,* 2021). Good tillage practices are good steps toward proper soil management as they reduce weed growth; incorporate fertilizer, manure and organic matter into the soil and speed up crops' growth (Lamidi *et al.,* 2021; Horton, 2019). Proper soil management is a key to sustainable agricultural production (Wang *et al.,* 2019). Most

commercial farmers in southwest Nigeria (a tropical humid region) use minimum tillage, some peasant farmers use zero tillage while few commercial farmers use maximum tillage systems, this was because of the high costs of hiring the relevant equipment.

Cassava can be processed into 'Gari', Cassava flour, '*Fufu'*, Tapioca, Cassava snacks and so on. The first three mentioned are common to the Southern Nigeria. Sustainability of gari business among women-in-agriculture depends on many factors, soil on which cassava grows is one of these factors. There have been many researches on cassava production and its derivatives in Nigeria (Ikuemonisan *et al.,* 2020; James *et al.*, 2012; Akinpelu *et al*., 2011; Ande *et al*., 2008) but literatures on the relationship between the cassava tubers produced and the tillage management practices are still few and especially, a statement whether tillage system on the soil may affect the quality of cassava tubers produced. The (not-yet documented) assertion from the responses to oral-questions that were asked from some women-in-gari production in Osogbo (Olorunda and Osogbo LGAs), Ifon-osun (Orolu LGA), Ilobu (Irepodun LGA), Ile Ogbo (Ayedire LGA), Iwo (Iwo and Ola-oluwa LGAs and Ejigbo (Ejigbo LGA) which were in eight of the thirty local governments areas (LGA) of Osun State on if end products of cassava tubers really depend on soil where it grows is yet to be scientifically proved. If their assertion is true, then cassava flour or Gari or *Fufu* derivatives from cassava roots will also depend on many factors namely season of the year, type of soil management on which it grows (which includes tillage methods), soil nutrients available and the breeds of cassava stems planted. The veracity of the women–in-gari /*fufu*/ cassava flour production needs to be researched into, if truly tillage as a soil management will affect the quality of the end products of cassava tubers. Hence, the objectives of this research were to investigate effects of various types of soil tillage methods on cassava plants production in the rain forest of Osun State and to determine the type of tillage practices that give optimum yield of cassava tubers with good quality tuber extracts toward efforts in sustainability of people's dietary lives and cassava production in the area.

2. MATERIALS AND METHODS

2.1 Site Selection

The research site, Aba Odan, has large expanse of unique arable land spanning over hundred hectares bounded by other research sites namely *Kejo, Ile Igbo* Station and *Eleni* villages, all in Osun State, Figure 1. An expanse of well-drained land of 2 acres with sandy-loam soil in Aba Odan village in Ile Ogbo, Ayedire Local Government Area of Osun State on 7° 30' 57" N, 4° 19' 30" E was used. The land had not been tilled for more than five years before clearing, this was to make sure that soil nutrients were intact. Osun State - South West Nigeria occupies approximately 14,875 sq. km, between longitude 4.545º'E; latitude 7.785ºN. Though, with clay deposit, hilly lands and rocks in some Local Government Areas (LGAs), 85% of this land mass is cultivable and about 80% (11,900 sq. km) of this supports cassava production (Osun State Diary, 2018). The soil-profile throughout the area where the research was conducted are almost uniform and in conformity with other parts of Osun State. Thereby, all portraying same geographic location and soils formed from the same parent materials. Hence, it is appropriate to say that the experiment in a part of the state may be a representation of the whole Osun State, Nigeria.

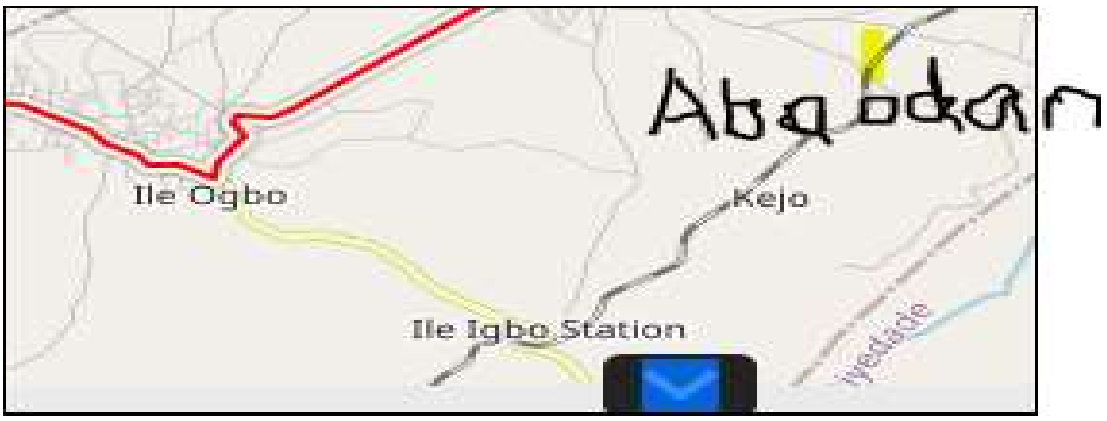

Fig. 1. Map of Aba Odan village (in yellow spot) with adjoining villages in Ile Ogbo environs

2.2 Soil Sample Preparation and Sample Analysis

Soil samples were air-dried, lightly crushed and passed through a 2 mm sieve. The fraction less than 2 mm was used for the determination of various soil parameters. Soil tests were carried out on the soil samples taken. The bounded areas to the research site Aba Odan also have their soil test analyses to know if there is any homogeneity of soil in the area. The results as shown in Table 1 show the homogeneity of the area and due to the homogeneity of the study area, site in each of the villages and the experimental sites were treated as a unit. The prove of homogeneity of the soil would ascertain that soil management system, that is, tillage practices could be the reason for the differences in the quality of cassava tubers produce at the end of the research.

The particle size was determined with the modified hydrometer method of (El Kebch *et al.,* 2019) using 0.2 M NaOH solution as the dispersing agent. Soil pH was determined with a glass electrode pH meter in distilled water using 1:1, soil: water, as described by Sainju *et al.*, 2021). Soil organic carbon was determined by the chromic acid digestion method reported by Husein *et al.,* 2019). Total N was determined by the macro-Kjeldahl method (Cao *et al.*, 2017) and available P by the Bray-1 method as described by Morad, (2020). Exchangeable cations (Ca^{2+}, Mg^{2+}, K^{+} and Na^{+}) were extracted with neutral solution of 1.0 M NH_4OA_C. The K^{+} and Na^{+} concentrations in the extract were determined using the flame photometer while Mg^{2+}, Ca^{2+} and the trace elements were determined using the atomic absorption spectrophotometer (AAS). The exchangeable acidity (H^{+} and Al^{3+}) was extracted using 1.0 M KCl (Dhillon and Raun, 2020). Aliquot of the extract was titrated with 0.05 M NaOH to a permanent pink endpoint using phenolphthalein as indicator. The amount of NaOH used was taken to be equivalent to the total amount of exchangeable acidity in the aliquot taken. The soil test is necessary in order to know if the nutrient content of the soil can sustain the productivity of the test crop.

2.3 Experimental Design

Three treatments were involved namely: zero tillage-0; primary or minimum tillage-1 and secondary or maximum tillage-2. Each treatment was replicated three times. 2 acres, (8,000 m^2) area was used in the site. 2,670 m^2 of land each was cultivated for each of the three treatments. Each treatment was divided into three plots (as

replicates) with designations 0A, 0B and 0C for zero tillage, 1A, 1B and 1C for the minimum tillage and 2A, 2B and 2C for the maximum tillage. Each of the plots was planted with 98/0581 bitter cassava species. For zero tillage, cassava stems were planted without tillage. Spacing was 120 cm by 90 cm, making a total of 9262.5 cassava plants per hectare. 100 kg of NPK fertilizer was applied to the crop 5 weeks after planting, because of low organic matter content on planting area that can sustain the crops, Akinrinde and Obigbesan 2000, for good growth and yield despite the land fallow. For minimum tillage, plots were ploughed once and latter sprayed with herbicides containing the active ingredient dimethyl 2, 4-D amine. For zero tillage, no any tillage was done, plots were sprayed with mixed herbicides containing the active ingredient of dimethyl 2, 4-D amine and Paraquat dichloride which each concentration was 825 g/L and 297 g/L was applied. In the plots for minimum tillage, ploughing was done once and for maximum tillage, it was ploughed twice followed by harrow and finally ridging

Wherever the soil was worked upon, it was done in such a way that the soil was allowed to flow laterally around the implement during the operations in order to have lower penetration resistance at the surface and sub-surface layer that can favour tuberization of cassava (Shittu *et al.*, 2023). Both the minimum and the maximum operations were done to the required standards respectively to be assured that plants had necessary conditions under the required tillage methods.

2.4 Selected Agronomic Parameters of Cassava Crop

The average heights of the cassava shoots for the first three months at 10 days intervals were measured using measuring tape. Similarly, widths (longest widths of the leaves) were also measured in every ten days, the averages were recorded. The random sampling of the heights of shoot and leaves' areas were taken in 3 replicates ($n_1 = 160$) and in whole plot ($n_2 = 480$). The average growth rates (increase in heights of cassava shoot per unit period of time (number of days) were calculated using initial and final heights during the days of measurement, Equation 1. The total cassava roots (per hectare) in each plot and their replicates were uprooted and weighed to record their yield/ha, this was done at the end of the nine months. Growth rate is the difference in growth over a specific period of time divided by the time interval in between, that is

$$Growth\ rate = \frac{Final.height - initial.height}{Number.of\ .days.in.between} \qquad (1)$$

2.5 Leaf Area Measurements

Leaf Area Index (LAI) is defined as the leaf area per unit ground area was calculated from measured data. The leaf area was determined through repeated area measurements on 'single leaf' and area (accumulation), these methods are hence considered the most accurate, and for that reason they are often implemented as calibration tools for indirect measurement techniques (Lamidi *et al.,* 2020). In this experiment, the model tree method- a direct method of measuring LAI was used. It consists of measuring the vertical distribution of leaf areas from the destructive sampling of a small amount of representative cassava plants out of the stands with even-aged plants like cassava plants of this research (with normal leaves' distribution, 3 or 5 plants' sampling was sufficient).

2.6 Proximate Composition of Cassava Paste

Some fresh cassava roots were randomly selected, processed into cassava paste using burr mill, this was to evaluate quality of the roots using proximate analysis via percent crude fibre and ash content (dry matter content), carbohydrate, crude protein and moisture content. The reason for using paste rather than cassava flour was to minimize the interference of possible external factors like fermentation, dewatering, sun drying or oven drying, milling or pulverizing and others, during their preparations. Such could have totally changed their compositions or interfere with them.

Crude protein of the paste was determined by micro-kjeldahl method (AOAC, 2019). Crude fibre and ash contents, moisture content and ether extract of the paste were determined by method explained by Simone *et al*., 2022) method. Each analytical method for each treatment ($n_{treatments}$=3) and each replicate ($n_{replicates}$=3) were done three (n_{trial} times=3) times (n=27). The proximate analysis of the cassava tubers was to ascertain the quality produced with reference to different tillage methods used.

2.7 Data Analysis

All collected data were analyzed using one-way analysis of variance – ANOVA. Regression analysis was used for LAI and average growth rate of cassava plants under different tillage methods. Where significant differences existed, treatment means were separated using Duncan Multiple Range Tests.

3. RESULTS AND DISCUSSION

The results of the soil analysis for the soil in each of the acreage of land used in the four different experimental sites are shown in Table 1. The results show that the mean values of different physical and chemical properties of the soil are not statistically different from one another for a parameter of the soil chemical properties. Thus the soil could not have significantly affected the cassava planted in each of the soil in each of the sites since the soil properties are not significant from a site to the other.

Table 1. Chemical and physical properties of soil before the experiment

Soil Parameters	**Values**			
	Aba Odan village	Kejo village	Eleni village	Ile Igbo Station
	Chemical Properties			
pH (H2O)	7.20a±0.61	6.63a±0.40	6.57a±0.53	6.97a±0.42
Organic matter (%)	2.39a±0.05	1.96b±0.03	1.41b±0.01	1.82b±0.02
Available P (ppm)	1.52b±0.02	1.59b±0.01	1.50b±0.02	2.58a±0.01
CEC, (meg/100g)	8.26a±0.54	7.60b±1.02	6.30b±0.45	8.10a±0.47
K (ppm)	32.12b±5.67	31.03b±0.01	40.15a±2.03	46.08a±2.02
Ca (ppm)	40.00a±5.02	34.20a±1.02	32.02a±4.03	29.00a±3.03
Mg (ppm)	35.40a±3.01	19.00b±2.02	29.80a±5.04	16.40b±2.04
Nitrogen (%)	0.72a±0.02	0.34a±0.01	0.52a±0.01	0.28a±0.01
Sodium (ppm)	42.33±3.89	26.63±3.42	32.50±6.01	38.58±3.03
Cu^{2+} (ppm)	1.15a±0.04	1.14a±0.01	1.29a±0.01	1.37a±0.01
Mn^{2+} (ppm)	99.37a±7.02	70.92b±6.07	80.50b±7.89	79.59b±2.02
Co^{3+} (ppm)	0.20c±0.01	1.26b±0.02	4.21a±0.20	1.38b±0.01
Fe^{2+} (ppm)	40.20a±3.40	37.6a±3.01	42.10a±3.56	42.77a±3.04
Zn^{2+} (ppm)	3.40a±0.12	1.03b±0.51	1.92b0.02	1.77b±0.02
	Physical properties			
Sand (g/kg)	640.30	683.90	800.40	700.20
Silt (g/kg)	230.40	203.05	49.40	172.50
Clay (g/kg)	129.30	113.05	150.20	127.30
Textural class	Sandy loam	Sandy loam	Sandy loam	Sandy loam

abc - Mean values with the same letter(s) along same row are not statistically different at ($p \leq 0.05$)

3.1 Heights and Mean Heights values of Cassava Plants for the first 90 days

Significant effects ($p < 0.05$) of minimum tillage and maximum tillage were observed ($p = 0.027$ and 0.014) on cassava yield, while no significant effect ($p > 0.05$) of zero tillage was observed ($p = 0.137$) on cassava yield at harvest. The results of the average heights and the resulted mean values were respectively given in Table 2 at 10, 20, 30, 40, 50, 60, 70, 80 and 90 days when the heights' growths were stabilized. Table 2 shows statistical differences among the mean values of the heights of cassava plants. Heights of shoot for maximum tillage were higher throughout the period. The mean values show significance between 10 and 50 days and at 80 days especially at maximum tillage.

Table 2. Mean values of heights of cassava shoots in the first three months

Days	Heights of cassava shoots in plots (cm)		
	Zero tillage (0)	Minimum (1)	Maximum (2)
10	5.28 ± 50.02^{c}	5.87 ± 20.00^{b}	6.12 ± 40.32^{a}
20	18.24 ± 40.080^{c}	19.03 ± 40.6^{b}	21.20 ± 50.22^{a}
30	27.40 ± 20.01^{c}	29.82 ± 51.14^{b}	30.02 ± 42.2^{a}
40	37.84 ± 20.24^{ab}	37.90 ± 39.17^{b}	40.63 ± 31.4^{a}
50	54.40 ± 30.3^{c}	71.10 ± 40.20^{b}	71.22 ± 36.8^{a}
60	90.00 ± 31.10^{b}	89.28 ± 40.21^{c}	90.52 ± 38.27^{a}
70	111.20 ± 22.32^{c}	112.00 ± 50.22^{b}	112.4 ± 40.22^{a}
80	129.40 ± 21.03^{c}	130.15 ± 38.13^{b}	131.90 ± 50.00^{a}
90	150.10 ± 18.55^{c}	149.00 ± 41.22^{b}	150.02 ± 48.22^{a}

^{abc}Mean values with the same superscript(s) along same row are not statistically different at ($p \leq 0.05$)

At early stage on growth, the internodes were smaller, whereas, internodes were longer at higher growth period in their heights with average 13.0 cm in zero tillage between 10 days and 20 days compare to 14.6 cm or 14.4 cm at between 40 and 50 days, these account for higher heights, the same goes for minimum and maximum tillage. The results of the heights of the shoot at 10 days interval showed the increasing values for maximum tillage than other two methods of tillage. Also, there were increase lengths and widths of the laminas for the maximum tillage than their respective zero tillage and minimum tillage. There were statistical differences among the mean values along the same row for each classification, Table 2.

3.2 Leaf Area Index (LAI)

LAI average values were close as the graph shows, but maximum tillage treatment slightly had high values than others as shown in the graphical representation, Fig 2. Leaf Area Index (LAI) increases as the number and size of individual leaves increase, reaching a peak at 210 days after planting. It must be noted that the LAI has increased values because of the canopy formed by the shoots (69, 70 and 72 m^2 for zero, minimum and maximum tillage respectively). Regression equations found from Figure 2, Equations 2 – 4 show that there were stronger relationships between methods of tillage and cassava leaves' growth as shown by their higher R^2 values (R^2 = 0.999, 0.998, 0.996). (In these equations, independent variable Y = methods of tillage and X = LAI average values of the leafiness of the cassava).

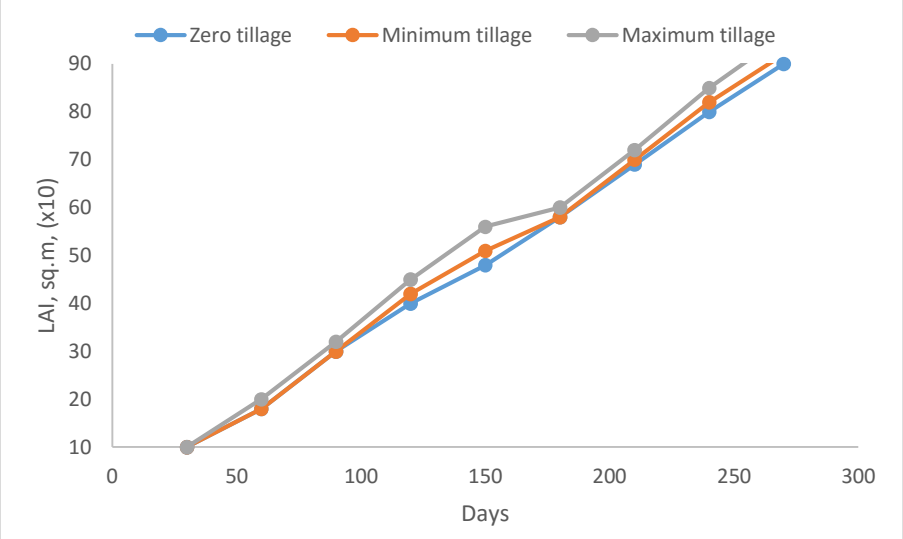

Figure 2.Average values of Leaf Area Index, LAI; is a dimensionless parameter

For zero tillage,

$$Y_{zero} = -0.0078\,X^3 + 0.0002\,X^2 + 0.3401\,X + 0.5397 \quad R^2 = 0.999 \quad \text{Equation 2}$$

For minimum tillage,

$$Y_{minimum} = -0.06\,X^3 + 0.0005\,X^2 + 0.3931\,X + 2.29 \quad R^2 = 0.998 \quad \text{Equation 3}$$

For maximum tillage,

$$Y_{maximum} = -0.006\,X^3 + 0.0014\,X^2 + 0.5312\,X - 5.84 \quad R^2 = 0.996 \quad \text{Equation 4}$$

Maximum tillage method gave more leafiness and shoots development and was the fastest growing. Leafiness of shoots leads to high photosynthetic rates of plants; and eventual slightly higher LAI values. This led to significant number of tonnes (greater

than 4 tonnes in all cases in the yield of cassava roots produced. Thus, at the time of formation of canopy, there was much initiation of canopy to intercept radiation which provided more water and nutrients at the period for rapid growth. In maximum tillage, soil undergone much needed pulverization and thereby with virtually all soil clods broken, the crop roots were able to respire and then were well developed and good soil aeration were ensured. It is obvious that maximum tillage made crops to do well because it allows the soil to be well aerated from the time of planting of cassava stems to the time of its harvesting. High LAI values could also be that maximum tillage obviously allows easy tillage of the soil around the mature roots (that may be ready for harvesting) thereby leading to easy uprooting of these roots. This easy tillage may equally summarizes the high yield recorded for maximum tillage which is 5.2% increase of maximum tillage over the zero tillage.

The extents of performance of different plots on the plants were evident on their heights in the first three months and in the growth rate and up to nine months, on the 0A, 0B and 0C replicates/plots. Cassava plant height values for zero tillage were lower than other tillage methods, this was because cassava plants were not quickly able to form canopy as in others, thereby, decreasing the rate of evaporation of water beneath the soil, around the cassava roots, this could have helped in the roots development.

3.3 Growth, Development and Average Yield of Cassava Roots

The mean values of area for the longest and widest leaves are recorded in Table 3. There were statistical differences ($p<0.05$) among the values recorded for each of the mean areas for the longest and widest leaves. Maximum tillage system had the highest areas for the leaves at 90 days and zero tillage had less. The graph of the growth rate in ninety days is shown in Fig 3.

Table 3. Mean values of area of cassava leaves in the first three months

Days	Classifications of leaves as to longest or widest					
	For the longest leaves, cm^2			For the widest leaves, cm^2		
	0	1	2	0	1	2
10	7.2 ± 70.01^{c}	8.0 ± 41.02^{a}	7.9 ± 22.1^{b}	2.2 ± 40.4^{c}	2.1 ± 38.1^{b}	2.2 ± 53.01^{a}
20	10.0 ± 50.02^{c}	9.8 ± 32.42^{b}	10.4 ± 31.6^{c}	4.1 ± 50.12^{b}	4.4 ± 22.21^{a}	4.0 ± 32.2^{c}
30	11.8 ± 20.4^{b}	11.1 ± 10.03^{c}	11.9 ± 21.41^{a}	4.4 ± 11.0^{a}	4.3 ± 18.8^{c}	4.3 ± 22.1^{b}
40	11.9 ± 24.3^{c}	12.0 ± 32.6^{b}	12.4 ± 12.08^{a}	4.5 ± 32.2^{b}	4.5 ± 32.0^{b}	4.5 ± 40.0^{a}
50	12.8 ± 70.2^{b}	12.6 ± 42.3^{c}	12.9 ± 30.04^{a}	4.8 ± 40.5^{b}	4.8 ± 10.02^{b}	4.7 ± 34.3^{a}
60	14.2 ± 40.0^{c}	14.5 ± 32.6^{b}	14.7 ± 44.11^{a}	5.0 ± 10.0^{b}	5.2 ± 30.0^{a}	5.0 ± 20.2^{b}
70	15.4 ± 30.24^{b}	15.3 ± 40.05^{c}	15.7 ± 160.4^{a}	5.6 ± 28.1^{b}	5.6 ± 30.3^{b}	5.8 ± 45.0^{a}
80	16.7 ± 82.06^{c}	16.7 ± 120.7^{b}	16.8 ± 110.3^{a}	6.3 ± 40.0^{c}	6.4 ± 60.0^{b}	6.6 ± 40.1^{a}
90	18.1 ± 112.7^{c}	18.4 ± 80.3^{b}	18.8 ± 120.02^{a}	6.7 ± 90.1^{c}	6.7 ± 85.02^{b}	6.8 ± 100.1^{a}

[abc]Mean values with the same superscripts along the same row for the same classification are not significantly different at 5% level.

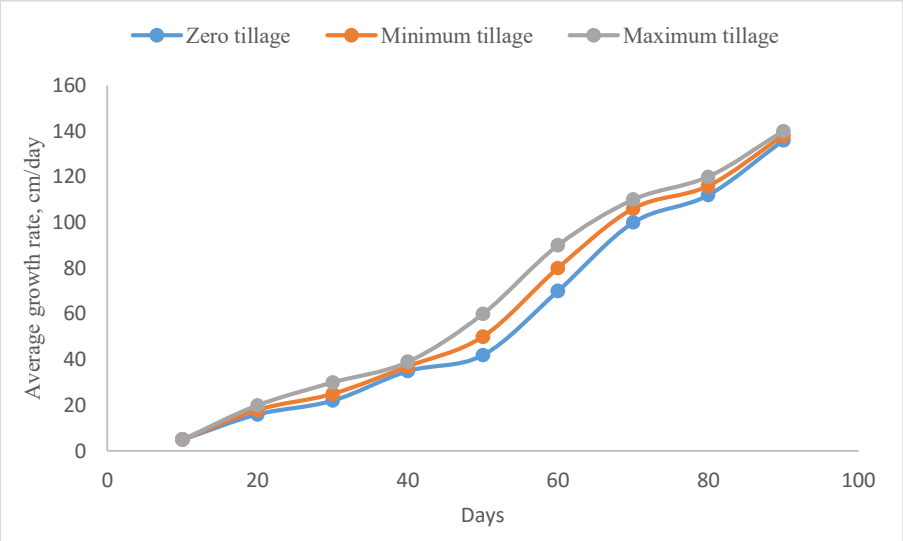

Figure 3. Average growth rate of cassava in 90 days

Maximum tillage has the highest average growth rate with 140 cm/day highest at the 90 days. Regression equations 5 – 7 for the treatments (independent variable Y, that is, methods of tillage) and Z (average growth rate values for cassava) show that there were stronger relationships between method of tillage and average growth rate as shown by their higher R^2 values (R^2 = 0.989, 0.991 and 0.992 respectively for zero, minimum and maximum tillage methods Figure 3.

$$Y_{zero} = -0.0001\,Z^3 + 0.035\,Z^2 - 0.562\,Z + 10.14; \quad R^2 = 0.989 \qquad \text{Equation 5}$$

$$Y_{minimum} = -0.0002\,Z^3 + 0.0431\,Z^2 - 0.166\,Z + 10.80; \quad R^2 = 0.991 \qquad \text{Equation 6}$$

$$Y_{maximum} = -0.0003\,Z^3 + 0.0447\,Z^2 - 0.0463\,Z + 8.262; \quad R^2 = 0.992 \qquad \text{Equation 7}$$

The harvesting was done after nine months of planting, it was found out that plots 2A, 2B and 2C replicates gave the highest yield in tonnes per hectare of 11.33 t/ha, 10.77 t/ha and 11.05 t/ha respectively or 2.5% higher in 2A than 2C. The zero tillage plots 0A and 0B gave the lowest yield of 10.2 t/ha, 10.3 t/ha and 10.77 t/ha respectively. These were not the same as the range of yield of cassava of 10 t/ha to 11 t/ha found in the country when all necessary requirements are available (Ikuemonisan *et al*, 2020; FAOSTAT, 2019). So also, from the yield received, the maximum tillage, though it was more capital intensive than other two methods of tillage, it was more profitable than others. Also, it have ease of harvesting as the roots' uprooting were easy because the soil was well aerated than the soil in the minimum and zero tillage plots. This was calculated from man-hours during the uprooting as same conditions of soil wetness (rain fell during the period to make soil moisture almost the same), same soil homogeneity, same equipment provided. Same men ((3 men) spent 3 hours for an acre in maximum tillage whereas four hours was sent per acre in the minimum tillage plot and 6 hours per acre in the zero tillage plot when all other conditions were the same (their fatigue was taken care of with in between days rest).

3.4 Quality Test on Cassava Roots

Significant effects ($p < 0.05$) of minimum tillage and maximum tillage methods were observed (respectively $p = 0.041$ and 0.008) on the quality of cassava paste. The

results of the mean values of the proximate analysis at the end of nine months when the roots were harvested are given in Table 4 with the results showing statistical differences ($p < 0.05$) among the values for crude protein, moisture, dry matter content, ether extract and ash content of the paste. This means that since the soil properties were not significant on the cassava tubers, then it must be the system of the management used, that is, the tillage method that must have been the reason for this significance. Between replicates, there were small range as $\pm$0.04, (difference between 0.77 and 0.81 for 1A and 1B respectively), for ether extract and $\pm$0.40, (difference between 19.60 and 19.20 for 1A and 1B respectively) for crude fibre for the minimum tillage. This may be surmised to show that the replicates have close values. The standard deviation shown for each value in Table 4 revealed the closeness of the values although with statistical differences among them.

Table 4. Mean values from the proximate analysis of the cassava paste

Treatment replicates	Mean proximate values, %				
	Protein	Ether Extract	Moisture content	Ash	Crude fibre
0A	1.54 ± 0.02^{ac}	0.31 ± 0.04^{bca}	76.48 ± 0.02^{a}	3.49 ± 0.00^{b}	18.18 ± 0.03^{abc}
0B	1.50 ± 0.04^{bcd}	0.28 ± 0.00^{ad}	76.48 ± 0.03^{a}	3.54 ± 0.03^{ab}	19.60 ± 0.01^{b}
0C	1.52 ± 0.00^{abd}	0.29 ± 0.02^{ad}	76.44 ± 0.02^{b}	3.56 ± 0.00^{a}	19.59 ± 0.02^{c}
1A	1.57 ± 0.00^{c}	0.77 ± 0.04^{c}	76.20 ± 0.0^{ab}	2.86 ± 0.04^{c}	19.60 ± 0.0^{bd}
1B	1.60 ± 0.01^{d}	0.81 ± 0.00^{bc}	75.60 ± 0.00^{c}	2.79 ± 0.02^{bc}	19.20 ± 0.01^{ca}
1C	1.59 ± 0.03^{abc}	0.88 ± 0.01^{d}	76.48 ± 0.00^{ac}	2.54 ± 0.01^{d}	18.51 ± 0.02^{ac}
2A	1.65 ± 0.00^{bc}	0.88 ± 0.02^{bcd}	75.20 ± 0.00^{bc}	2.77 ± 0.02^{ca}	19.50 ± 0.02^{abc}
2B	1.68 ± 0.01^{ab}	0.94 ± 0.04^{ab}	76.80 ± 0.02^{d}	2.10 ± 0.01^{ad}	19.48 ± 0.01^{ab}
2C	1.70 ± 0.02^{a}	$0.98 \pm 0.01^{a**}$	74.40 ± 0.00^{e}	2.54 ± 0.00^{bd}	20.38 ± 0.00^{c}

^{abc}Mean values with the same superscripts along the same column are not significantly different at 5% level.

3.5 Plant Heights and Growth Rate Mean Analysis

The resulted considerable nodes' distance observed in the shoot depicted that cassava shoots developed new branches almost every week in all the treatments. This was a result of some factors like common genotypes, similar levels of soil fertilities and same climatic conditions. The increase in node distance from each other gave rise to the heights recorded and since maximum tillage had more height than others, it is only reasonable to say that it has highest development than others within the same period of time.

3.6 Quality Test on Cassava Roots

The proximate composition of the different cassava roots from each method of tillage got from proximate analysis shows statistical differences among the mean values implying that the different tillage operations have significant influence on the proximate compositions of the cassava roots. There are obviously some capabilities of these cassava roots to reach where nutrients are located in the soil for absorption to carry their out photosynthetic roles and thereby resulting in eventual significant levels of roots development which also affect the roots' contents giving rise to statistical differences in the proximate values recoded. Thus, the quality of the cassava roots was affected by different tillage methods and was better in the maximum tillage than other methods of tillage. Therefore, maximum tillage if practiced will help to increase the nutrient contents in the cassava tubers in the area where the experiment was carried out, implying that more nutrients will be delivered to the people, thus solving the sustainable development goals SDG of the United Nations (UN) number 1,

poverty eradication, 2, zero hunger and 3 good health and well-being of Aba-Odan and the environs There may be other possibilities like the nature of soil where the cassava was grown, the prompt removal of weeds from the plot at due time that curb any external agents' invasion and the seasons of the year that might have caused differences in paste's quality differences.

4. CONCLUSION

Tillage practices significantly affect the height, LAI, yields and the proximate quality of the cassava roots. The maximum tillage cassava plot was better in term of plant heights reached, length of leaves and proximate quality than minimum or zero tillage and resulted in more nutrients in the cassava roots in the maximum tillage. If maximum tillage is practiced by the farmers in the study area, sustainable development in term of good health and wellbeing and zero hunger will be achieved. There will also be more profit margin which will increase their welfare and their standard of living. Maximum tillage, because of its higher yield got in the research, may be recommended for soil and cassava tuber production and the higher productivity of maximum tillage plot over others.

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